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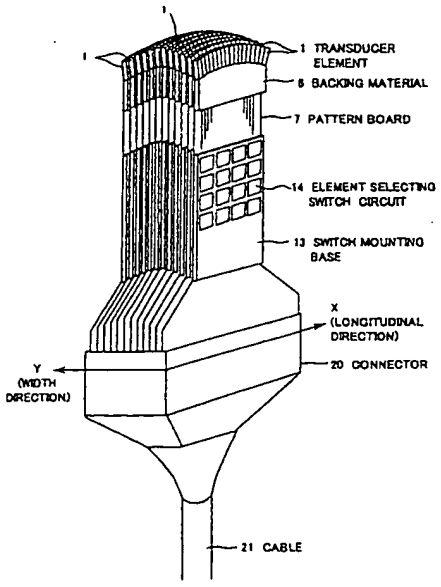
(54) ULTRASONIC PROBE AND ULTRASONIC DIAGNOSTIC DEVICE COMPRISING THE SAME

(57) An ultrasonic probe in which two-dimensional array transducer elements are arrayed convexly both in one direction of the two-dimensional array and in the direction perpendicular to the former direction relative to the direction where an ultrasonic wave is transmitted. By switching a transducer element selecting switch circuit provided near the transducer elements, the shape of the diameter of the probe for transmitting and receiving of ultrasound and the position of the diameter are arbitrarily determined. An ultrasonic diagnostic apparatus in which a fresnel ring is formed as an diameter by a control signal to a transducer element selecting switch circuit, the number of cables for connection between the probe and the main body is decreased by bundling the transducer elements in one ring and effecting the connection, the fresnel ring is moved every ultrasonic transmission/reception cycle by the control signal to the transducer element selection switching circuit, and an object is three-dimensionally scanned with an ultrasonic beam.

Fig.1



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Description

FIELD OF THE INVENTION

[0001] This invention relates to an apparatus for scanning an object to be examined three-dimensionally with an ultrasonic beam, particularly to an ultrasonic two-dimensional array probe being capable of scanning the object three-dimensionally with an ultrasonic beam by an electronic control and an ultrasonic diagnostic apparatus comprising it.

BACKGROUND OF THE ART

[0002] Recently an ultrasonic diagnostic apparatus was developed that transmits and receives an ultrasonic beam with an ultrasonic probe, scans the object three-dimensionally, corrects three-dimensional data from the object, and makes a three-dimensional image for diagnosis. In the first example of such an apparatus, the three-dimensional image data is corrected by moving an ultrasonic probe with a plurality of transducer elements arranged in one direction parallel and mechanically on the surface of an object. The scanning is performed from side to side by inclining consecutively a contact angle of the probe to the object without changing the contact position between the probe and the object.

[0003] In addition, in a second example, a 2D-array ultrasonic probe is composed with 64×64 elements arrayed two-dimensionally. An ultrasonic beam with gimlet shape is transmitted and received in or from the interior of the object by using specified transducers fixedly selected in the 2D arrangement, and a three-dimensional image data from the object to be examined is corrected. In addition, the two-dimensional probe is a probe whose arrangement of elements is expanded from one direction to two directions. For example it is disclosed in Ultrasonic Imaging 14, 213-233 (1992); IEEE Trans. UFFC 38, 100-108 (1991).

[0004] However, the disadvantage of the traditional ultrasonic diagnostic apparatus is that the ultrasonic probe and the ultrasonic diagnostic apparatus have to be large and heavy because a driving system for the scanning ultrasonic beam and for moving the probe mechanically is necessary. Therefore, from an operational view, a small and light two-dimensional probe is desired. As the scanning range is basically restricted by the composition of the driving system, an arbitrary range cannot be scanned. Furthermore, the mechanical scanning mechanism causes abrasion. Therefore, the lifetime of the probe is short.

[0005] The disadvantage of the second ultrasonic apparatus is further that only the fixedly selected transducer elements in the two-dimensional array are used for transmitting and receiving an ultrasonic beam with gimlet shape. Therefore, the region for correcting the three-dimensional data is narrow. In addition, an even transducer element number used for transmitting and receiving is specified as a part of 64×64, but necessarily of about 256. So a lot of cables connected to each element are needed. If the number of transducer elements for transmitting and receiving ultrasound is increasing, a lot of beam forming circuits disposed on the main body of the diagnostic apparatus are also needed.

[0006] Thus in view of the previously described subject matter, the object of the present invention is to provide a small and light ultrasonic probe that is able to scan an object three-dimensionally by transmitting and receiving an ultrasonic beam but having a reduced number of cables for connecting the ultrasonic probe and the main body of the diagnostic apparatus and which two-dimensional array probe focus dynamically.

[0007] In another embodiment of the present invention a two-dimensional array probe is provided with is designed to easily contact the surface of the object to be examined.

[0008] A further embodiment of the present invention provides an ultrasonic probe that is able to scan to the object to be examined three-dimensionally with an ultrasonic beam without using a mechanical scanning mechanism.

[0009] In another embodiment of the present invention, an ultrasonic probe is provided with which a three-dimensional image data can be acquired from a wide range of objects to be examined.

[0010] A further embodiment of the present invention provides an ultrasonic diagnostic apparatus designed that an operator is not influenced by the weight and the hardness of cables during operation.

[0011] Furthermore, in another embodiment of the present invention the ultrasonic diagnostic apparatus is capable to transmit and receive an ultrasound with a two-dimensional array probe and has few beam forming circuits.

[0012] A further embodiment of the present invention provides an ultrasonic diagnostic apparatus, which obtains good quality images.

DISCLOSURE OF THE INVENTION

[0013] In order to achieve the object, a first embodiment of the present invention comprises a plurality of transducer elements for transmitting and receiving an ultrasound, which are arrayed two-dimensionally and correct an ultrasonic signal. The plurality of transducer element is arrayed in one or two directions with convex shape to the transmitting direction of the ultrasound, wherein the two directions are perpendicular to each other. In case the ultrasonic probe has a convex shape in both directions, the transducer elements arrangement is preferable a radial arrangement in both directions, or a radial arrangement in one direction and a parallel arrangement in the other direction.

[0014] The ultrasonic probe of a further embodiment of the present invention has an element selecting switch circuit for selectively switching arbitrary transducer ele-

ments for transmitting and receiving ultrasound. The switch circuit is arranged in the vicinity of the two-dimensional array transducer elements. Output lines of the element selecting switch circuit are connected to each arrayed transducer element but the number of input lines is less than the number of the arrayed transducer elements.

[0015] In another embodiment of the present invention, an arbitrary transducer element can be selected by a control signal transmitted to the element selecting switch circuit. Accordingly, a diameter with an arbitrary shape can be formed. In addition, the diameter can be moved by transmitting the control signal to the element selecting switch circuit. With the motion of the diameter, a three-dimensional scan of the interior of an object is possible.

[0016] In another embodiment of the present invention, an ultrasonic diagnostic apparatus comprises the ultrasonic probe with two-dimensionally arrayed minute transducer elements. The apparatus further includes an element selecting means for supplying data to select transducer elements transmitting and receiving ultrasound from the array transducer of the ultrasonic probe, a means for supplying bundling data for bundling and connecting the selected transducer elements to a plurality of groups, a means for transmitting ultrasound to the object by applying a predetermined transmitting delay time to the bundled transducer element groups, a means for beam forming by receiving signals of the each bundled transducer groups, a means for image processing an output signal of this beam forming means, and an image display means.

[0017] In this embodiment the transducer elements are bundled to a plurality of groups and form a fresnel ring having a concentric circle. The ring is designed that the difference between a maximum and a minimum distance between the transducer elements in each ring forming the fresnel ring and the ultrasonic focus point, is less than 1/8 wavelength of the ultrasound.

[0018] In another embodiment of the ultrasonic diagnostic apparatus, the form of the fresnel ring is not changed during receiving an echo signal. Further, a means for controlling the beam forming circuit corresponding to the received signal of each ring is comprised for moving the receiving focus point continuously on the center axis line of the fresnel ring. Furthermore, the embodiment of the apparatus comprises a means for changing the form of the fresnel ring corresponding to the depth of the receiving focus point, a means for ultrasonic scanning the predetermined depth region of the object with each form of the fresnel ring, and a means for composing an image from an echo signal acquired at each depth region.

[0019] Moreover, an other embodiment of the ultrasonic diagnostic apparatus preferably comprises a two-dimensional array probe for transmitting and receiving ultrasound, a main body of the diagnostic apparatus for acquiring and displaying an ultrasonic image for the diagnosis of a part in the object's interior by using an ultrasonic signal corrected with the two-dimensional array probe, and a data transmitting part for transmitting selecting data for transducer elements and the corrected ultrasonic signal from one direction to another between the two-dimensional array ultrasonic probe and the main body.

BRIEF DESCRIPTION OF THE DRAWING

[0020] Fig.1 is a perspective view showing an embodiment of an ultrasonic probe of the present invention for showing the interior structure of it.

[0021] Fig.2 is a perspective view showing the structure of one line of the transducer elements in the longitudinal direction.

[0022] Fig.3 shows a plurality of the transducer elements of Fig. 1 arranged in longitudinal direction.

[0023] Fig.4 shows a plurality of the transducer elements of Fig. 1 arranged in transversal direction.

[0024] Fig.5 is a view showing the outline of the element selecting switch circuit combined in the two- dimensional probe of Fig.1.

[0025] Fig.6 is a perspective view showing the interior structure of a modified example of the two-dimensional ultrasonic probe of the present invention.

[0026] Fig.7 is a block diagram showing an embodiment of an ultrasonic diagnostic apparatus of the present invention.

[0027] Fig.8 is a view showing a use embodiment of ultrasonic diagnostic apparatus shown in Fig.7.

[0028] Fig.9 is an operation diagram for scanning the object three-dimensionally with an ultrasonic beam with selected diameter.

[0029] Fig.10 is a view showing a fresnel bundled connection of the probe and a delay circuit.

[0030] Fig.11 is a view showing an ultrasound transmitted by fresnel bundling.

[0031] Fig.12 is a view showing an ultrasound received by fresnel bundling.

[0032] Fig.13 is a beam simulation view for the effectiveness of the fresnel bundling in the present invention.

THE BEST MODE FOR CARRYING OUT THE INVENTION

[0033] Hereinafter embodiments of the present invention will be described in detail referring to the attached figure.

[0034] Fig.1 is a perspective view showing an embodiment of an ultrasonic probe of the present invention. The ultrasonic probe comprises a plurality of transducer elements arranged two-dimensionally for transmitting and receiving ultrasound to an object to be examined. In the ultrasonic probe, the plurality of transducer elements 1, for example 12,488 elements, are arranged in longitudinal direction (X direction) and in transversal direction (Y direction) with 196 × 64 elements, or 6,244

of the fresnel ring need not be changed. This is a characteristic of the present invention. The element bundling in the processing of received signal is not needed. So both - fresnel bundling and receiving dynamic focusing - can be performed. Moreover, the receiving dynamic focus can easily be performed.

Claims

1. An ultrasonic probe having a plurality of transducer elements arranged two-dimensionally for transmitting and receiving ultrasound, wherein said plurality of transducer elements is arranged with convex shape in two directions being perpendicular to each other relative to the ultrasound transmitting direction.

2. The ultrasonic probe of claim 1, wherein an element selecting switch circuit for selecting an arbitrary transducer element is disposed in the vicinity of said two-dimensionally arranged transducer elements for performing the transmitting and receiving of ultrasound.

3. The ultrasonic probe of claim 2, wherein said element selecting switch circuit has output lines for connecting each transducer element, input lines wherein the number of input lines is less than the total number of arranged transducer elements, and a control line for inputting a control signal for performing a transducer selecting change.

4. The ultrasonic probe of claim 2, wherein a control signal given to said element selecting switch circuit selects an arbitrary element from a transducer elements array to form a diameter of transmitted and received ultrasound, and this diameter is movable to an arbitrary position at each ultrasound transmitting and receiving cycle.

5. The ultrasonic probe of claim 4, wherein said diameter is moved in two directions of the two-dimensional array of transducer elements in a predetermined order.

6. The ultrasonic probe of claim 1, wherein the two-dimensionally arranged transducer elements are arrayed radially in one and the other direction of the arrangement.

7. The ultrasonic probe of claim 6, wherein an ultrasonic transmitting and receiving face of the transducer elements is formed convexly and radially with a radius of 60mm and a circular angle of about 68 degrees in one direction of the arrangement, and in the other direction with a radius of 32 mm and a circular angle of about 48 degrees.

8. The ultrasonic probe of claim 1, wherein the two-dimensionally arrayed transducer elements are arrayed radially in one direction, and parallel along the center axis of a circle in the other direction.

9. The ultrasonic probe of claim 8, wherein an ultrasound transmitting and receiving face of the transducer elements is arrayed convexly and radially with a diameter of 60mm and a circular angle of about 68 degrees.

10. An ultrasonic probe having a plurality of transducer elements for transmitting and receiving ultrasound in two directions, wherein said plurality of transducer elements is arrayed convexly to the ultrasound transmitting direction at least in one direction of the two dimensional array or another direction perpendicular to said direction of the two dimensional direction.

11. The ultrasonic probe of claim 10, wherein a switch circuit for selecting a transducer element from said two-dimensional arrayed transducer elements is disposed to form an ultrasound transmitting and receiving diameter which is smaller than the length of both sides of the two-dimensional arrangement.

12. An ultrasonic diagnostic apparatus comprising;

    an ultrasonic probe with two-dimensionally arrayed minute ultrasonic transducer elements,
    an element selecting means for selecting transducer elements to perform the transmitting and receiving of ultrasound from a transducer of said elements array ultrasonic probe,
    means for supplying bundling data to said element selecting means for bundling and connecting transducer elements to a plurality of groups,
    means for transmitting ultrasound to an object with a predetermined transmitting delay time for each bundling connected transducer element group,
    means for beam forming each receiving signal output from said bundling connected transducer element group,
    means for image processing an output signal of the beam forming means, and an image display means.

13. The ultrasonic diagnostic apparatus of claim 12, wherein the plurality of bundling connected transducer element groups form a fresnel ring of concentric circle.

14. The ultrasonic diagnostic apparatus of claim 13, wherein the difference of a maximum and a minimum of the distance between the transducer ele-

ments forming a fresnel ring in each ring and an ultrasonic focus point is less than 1 / 8 wave length of ultrasound.

15. The ultrasonic diagnostic apparatus of claim 13, wherein the means for controlling said beam forming circuit is composed to receive a signal of each ring such that the receiving focus point is moved continuously on the center line of the fresnel rings without changing the form of said fresnel ring in the receiving period of an echo signal.

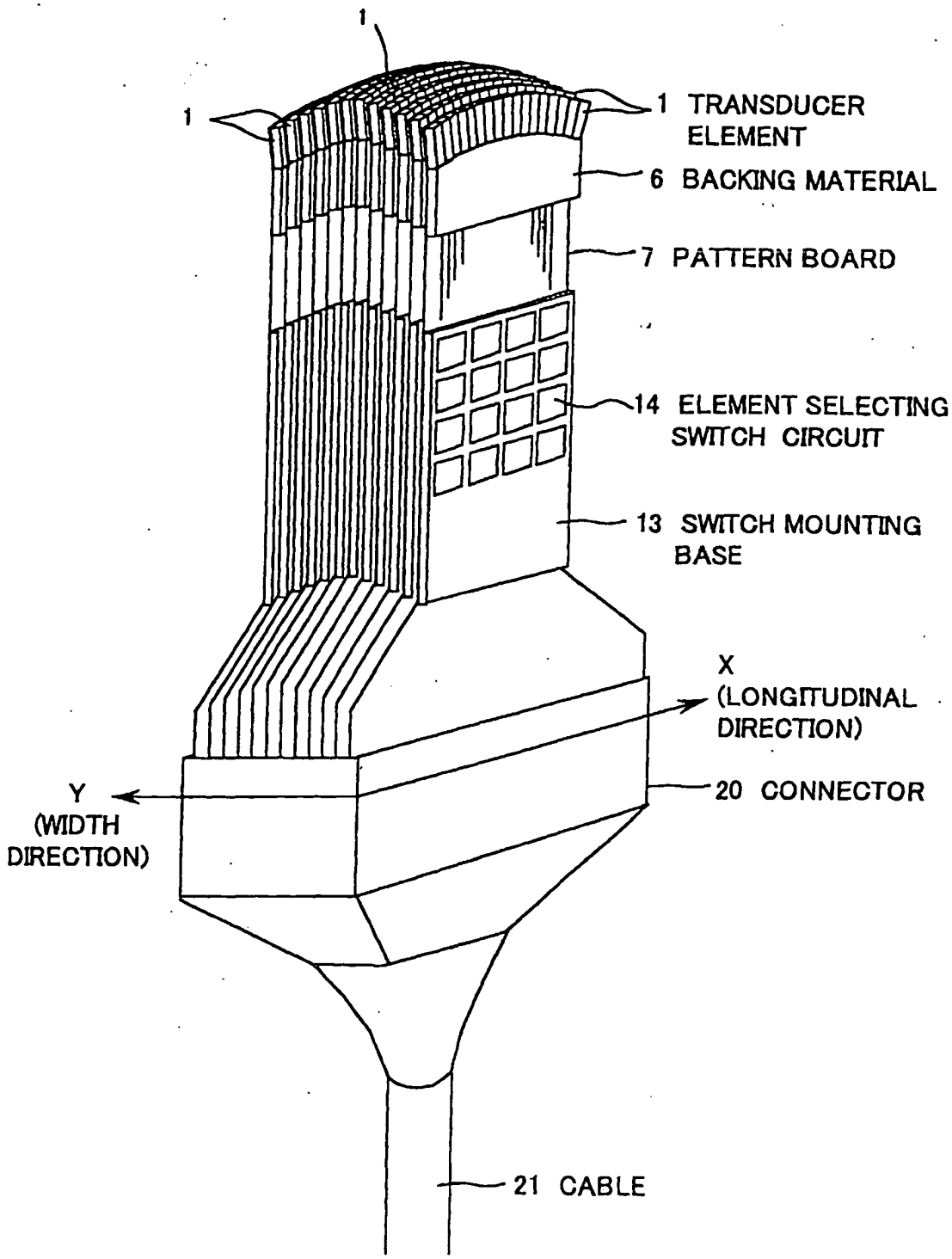
16. The ultrasonic diagnostic apparatus of claim 13, wherein a means for changing the form of said fresnel ring corresponding to the depth of receiving focus point is provided.

17. The ultrasonic diagnostic apparatus of claim 16, wherein a means for scanning the predetermined region of depth within the object at each form of said fresnel ring, and for composing an image from an echo signal acquired at each region of depth is provided.

18. An ultrasonic diagnostic apparatus comprising;

a two-dimensional array ultrasonic probe for transmitting and receiving ultrasound to an object,
a main body of a diagnostic apparatus for acquiring and displaying an ultrasonic image of a diagnosis part in the interior of the object by using an ultrasonic signal corrected with said two-dimensional array probe,
a data transmitting part for transmitting a selecting data of transducer elements and the corrected ultrasonic signal between said two-dimensional array ultrasonic probe and said main body, and for connecting the probe and the main body.

Fig.1


1
1
1
1 TRANSDUCER ELEMENT
6 BACKING MATERIAL
7 PATTERN BOARD
14 ELEMENT SELECTING SWITCH CIRCUIT
13 SWITCH MOUNTING BASE
X (LONGITUDINAL DIRECTION)
Y (WIDTH DIRECTION)
20 CONNECTOR
21 CABLE